FAIRCHILD

DU MONT LABORATORIES
SCIENTIFIC INSTRUMENT DEPARTMENT

Cathode-Ray Tube Phosphors

INSTRUMENTATION TECHNOLOGY FROM FAIRCHILD

APPLICATION NOTE **NO. 101**

In the cathode-ray tube it is the function of the phosphor screen to convert the kinetic energy of the electron beam into luminous energy. Cathode-ray tube screens are composed of phosphor particles which have an average size between 2 and 20 microns. (1 micron is 10^{-6} m). For maximum light output, efficiency and resolution, the size of the phosphor particles and thickness of the screen must be carefully controlled. Screens are deposited in many ways, but the primary method is that of settling by gravity out of an aqueous suspension. This method employs the use of a liquid medium through which phosphor particles are deposited in a uniform and controlled manner onto the glass faceplate of the CRT. Luminescence, persistence emission spectra, and conversion efficiency are characteristics unique to a given type of phosphor. Since the screen characteristics are primarily determined by the physical and chemical properties of the phosphor, the user's requirements will determine the best choice of phosphor for a specific application. A review of basic characteristics of phosphors which apply to oscillography and Fairchild Scientific Instruments is discussed in this application note.

FLUORESCENCE

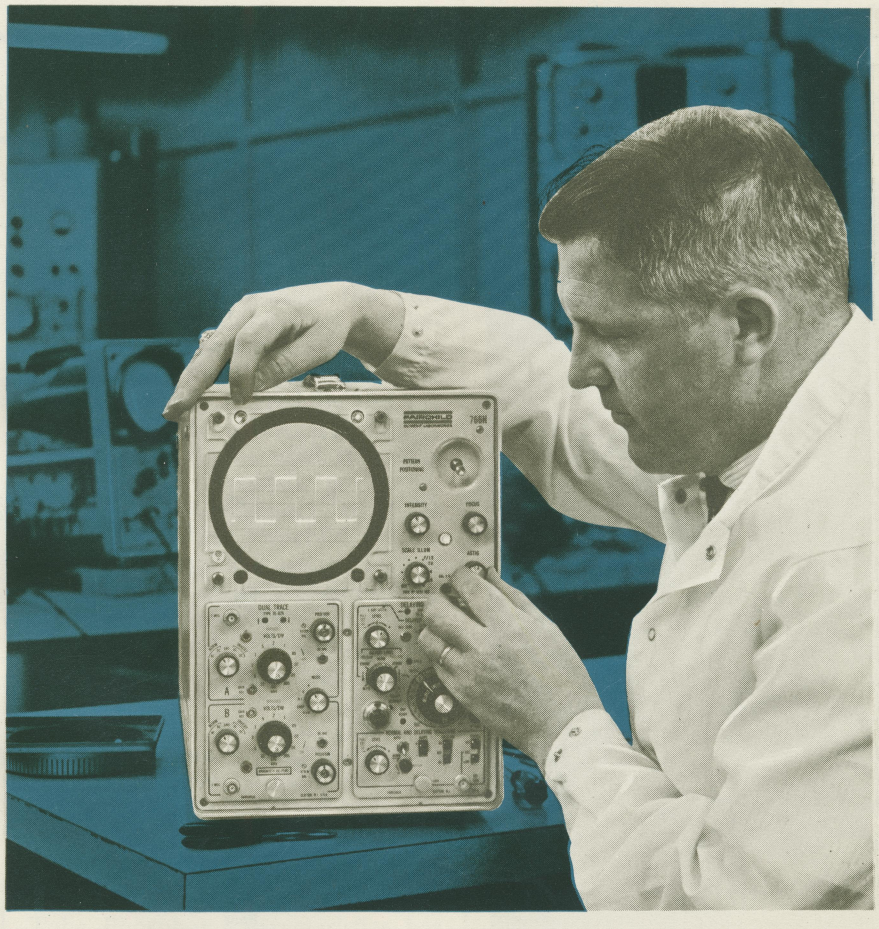
is the light emission occurring while the phosphor is excited. In the case of an oscilloscope the excitation is due to the electron beam. Therefore, as the beam moves on the phosphor the point of fluorescent light output coincides with the electron beam.

PHOSPHORESCENCE (AFTERGLOW)

is the light emission occurring after the excitation has been removed. When the electron beam is turned off, the phosphor does not immediately stop emitting light but extinguishes at some specific rate determined by the type of phosphor. There may sometimes be a difference in color between the color of the fluorescent spot (under excitation) and the phosphorescence (afterglow).

PERSISTENCE

is the relative duration of the phosphorescent emission. The time required for the intensity to decay to 10% of its initial value (fluorescent emission) is usually specified for comparison purposes. TABLE I compares the various phosphors used in



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oscillography to the standard categories of persistence. Some phosphors, such as P7, are deposited in two layers, each of which have widely separated persistence characteristics. The P7 phosphor persistence in Table I is a combination of both phosphor components. Decay curves (figure 1) of various phosphors commonly used in oscilloscopes are shown grouped into the persistence categories of Table 1. Each component of the P7 phosphor is shown separately.

Table I

Persistence Description	Time to Decay to 10% of Initial Brightness	Phosphor Type	Time Duration to 10% Point
Very Long	1 sec and over 100 ms to 1 sec	Not generally used in oscillography	—
Long		P7	400 ms
Medium	1 ms to 100 ms	P1 P4	24.5 ms 33 ms
Medium-Short	10 μs to 1 ms	P31 P2, P2B P11	70 μs 70 μs 60 μs
Very Short	Less than 1 μs	Not generally used in oscillography	—

BURN RESISTANCE

In general, only about 5% of the kinetic energy of the electron beam is converted into light output. The remaining energy is dissipated as heat. Heat generated from a well focused electron beam, if allowed to remain in one spot for a period of time, will reduce the luminous characteristics of the area. The light output of this area will be reduced and a dark spot (Burn) will appear under excitation. Relative values of burn resistances are listed for the various phosphors used in Fairchild Oscilloscopes (Table II). P31, the standard phosphor supplied with Fairchild Oscilloscopes, has been arbitrarily given the value of 100 as a basis for comparison. Phosphors having lower numerical values are more susceptible to burn damage.

RELATIVE VISUAL BRIGHTNESS

The relative brightness listed in TABLE II is qualitative rather than quantitative. Numerical values have been normalized against the P31 phosphor which has been given the value of 100. Although other factors must be considered, in general the phosphors which have brighter traces will also have a higher value of relative burn resistance.

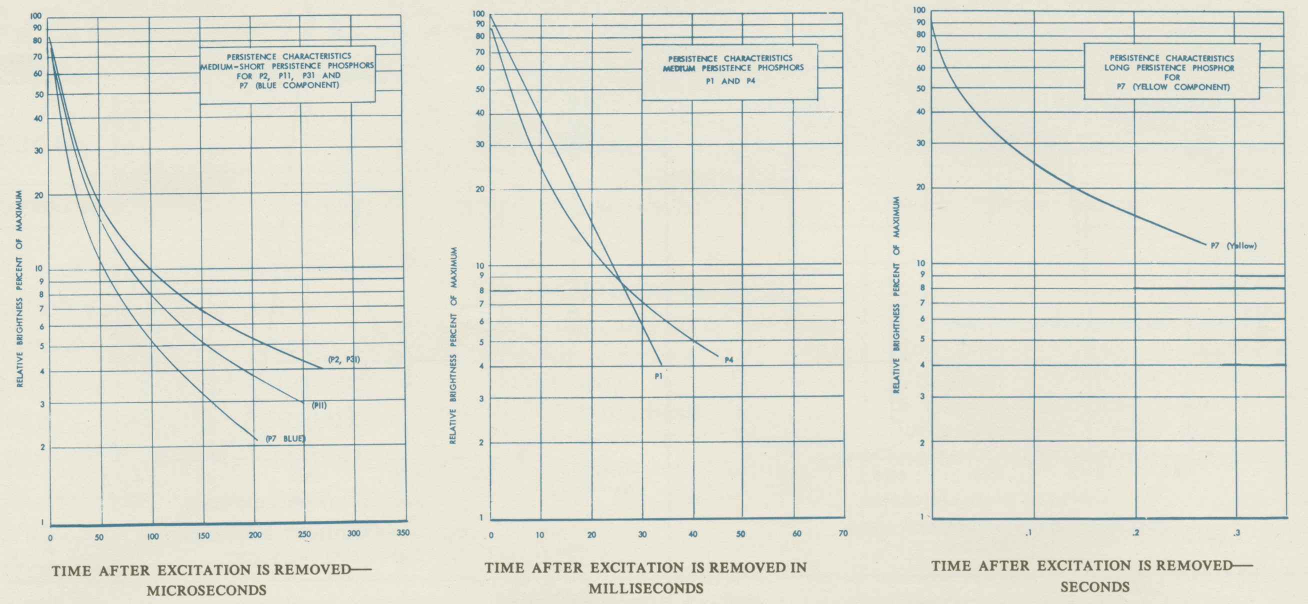
Table II

REFERENCE CHART FOR CATHODE-RAY TUBE PHOSPHOR CHARACTERISTICS

Phosphor	Color Fluorescence	Phosphorescence (afterglow)	Spectral Peak Millimicrons (Mμ)	Persistence	Relative Burn Resistance	Relative Brightness	Trace Contrast	Absolute Efficiency	Chemical Composition	Applications	General
P1	Yellowish-Green	Yellowish-Green	525	Medium (24.5 ms)	40	64	Good	6%	Zinc Silicate; Manganese	General purpose for low voltage oscilloscopes.	Good trace to background contrast; color near center of visible spectrum. Satisfactory for stationary pattern recording. Yellow component makes phosphor unsatisfactory for continuous motion or transcient recording.
P2	Yellowish-Green	Yellowish-Green	535	Medium (70 μs)	60	74	Fair	7%	Zinc Sulfide; Copper	General purpose for higher voltage oscilloscopes.	Trace color makes P2 good for photographic recordings of stationary patterns.
P7	Blue-White	Yellow	440 555	Long (400 ms)	30	40	Poor	*	Zinc Sulfide; Silver & Zinc Cadmium Sulfide; Copper	Long persistence applications when slow repetition rates or non-repetitive patterns are to be observed.	Since yellow and blue components are widely spread they can be selected by using a filter.
P11	Blue	Blue	460	Medium-Short (60 μs)	30	80	Poor	10%	Zinc Sulfide; Silver	Recording of high speed transients; reduces blurring with continuous motion cameras.	Limited use — mainly for photorecording.
P15	Green	Green	390 505	Short (2.8 ms)	25	18	Good	5.1%	Zinc Oxide	Flying spot scanners, continuous motion recording.	Less blurring than P11 in continuous motion recording. Very good for visual use with green filter and for photographic use without filter.
P16	Bluish-Purple	Bluish-Purple	385	Very Short (0.12 ms)	3	8	Poor	4.9%	Calcium Magnesium Silicate	Flying spot scanners with shortest persistence requirements, near ultraviolet applications.	Least burning of all phosphors in continuous motion recording.
P31	Green	Green	525	Medium-Short (70 μs)	100	100	Fair to Poor	22%	Zinc Sulfide; Copper	General purpose oscilloscopes.	Similar to P2, but has high light output and less danger of screen burns.

*double phosphor

Figure 1

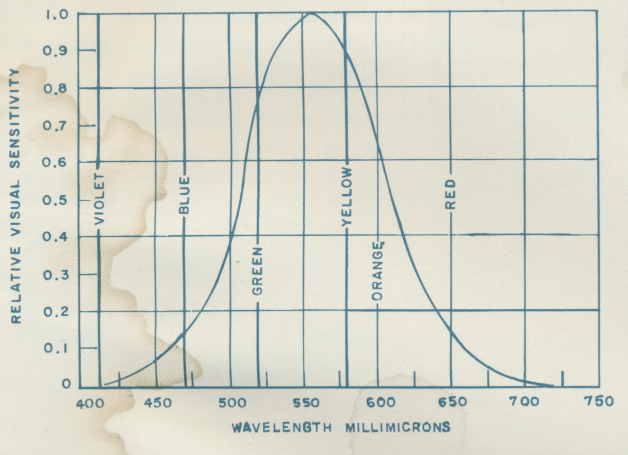


SPECTRAL RESPONSE

Two methods can be used to determine the emission color of phosphors. One method uses a spectrometer to obtain a spectral energy distribution curve. This curve is a plot of the relative amount of light emitted as a function of its wavelength. The wavelength is usually plotted in millimicrons (10^{-9}m). Curves of some of the more frequently used oscilloscope phosphors are included for comparison. Figure 2 relates the spectral response of the eye to wavelength and color. Color characteristics obtained in this manner are very useful in photographic applications. It can be observed that P7 phosphor has two peaks which are separated by over 100 millimicrons. This is because two different layers of phosphor are used to make the P7 screen.

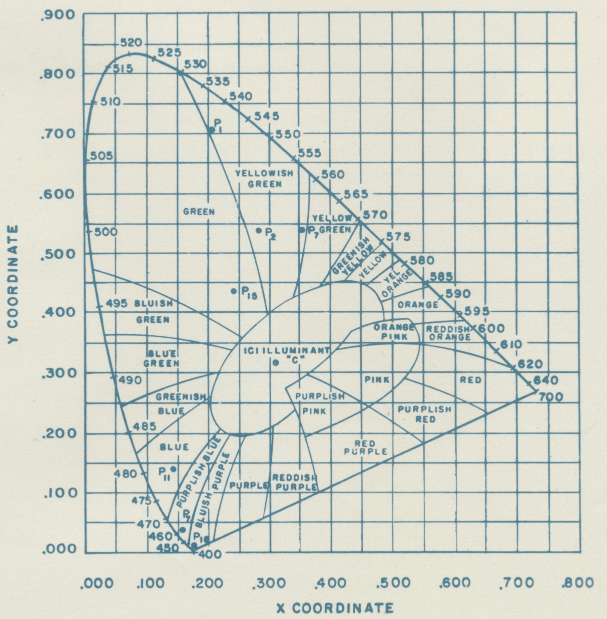
A second method relates the color of the phosphor by the amount of the three primary colors: red, green and blue; which are present in the emitted light. These are used as coordinates on a graph called a Kelly Chart. It is divided into 22 color categories which correspond to the color sensitivity of the human eye (figure 3).

Figure 2



SPECTRAL SENSITIVITY RESPONSE CURVE
OF HUMAN EYE

Figure 3



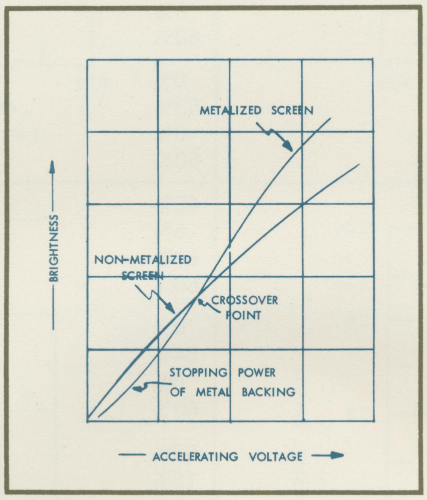
CIE CHROMATICITY DIAGRAM SHOWING
COORDINATES OF SEVERAL PHOSPHORS
(KELLY CHART)

METALIZING

Metalizing of a cathode-ray tube is accomplished by bonding a very thin layer of metal, usually aluminum (0.1 micron thick), over the phosphor. This metal layer must be very thin or much of the kinetic energy of the electron beam will be lost in penetrating the metal. There are four reasons for metalizing.

1. Obtain greater light output.
2. Increase the relative burn resistance of the phosphor.
3. Reduce the charge build-up on the screen which may cause pattern distortion.
4. Reduce cathode glow which may fog photographic time exposures.

Metalizing increases the brightness of the trace by reflecting a large part of the light which is normally radiated away from the viewer and lost through the face of the tube. The effect of metalizing on brightness will vary depending upon the accelerating potential of the CRT. Below 3 kv there will be little increase in trace brightness, since the loss in kinetic energy by the beam in penetrating the metal layer is a considerable part of the total beam energy. As the accelerating potential is increased, the energy loss due to the metal layer becomes a small part of the total kinetic energy of the beam and a cross-over point is reached. Above this point a brighter trace is obtained. The relative increase in brightness of the P31 phosphor will be approximately 2.5 times at an accelerating potential of 5 kv, and 3.5 times brighter at 10 kv. Metalizing also helps to reduce the danger of burning the screen since the electron beam does not have to be as intense on the metalized tube to produce the same light output as a non-metalized type. Metal backing on phosphors also serves to conduct local heat away and therefore reduces the danger of screen burn.



When the tube is constructed, the aluminum layer is connected to the aquadag coating on the inside of the tube. This provides a lower resistance path for the electrons to drain off the screen. In non-metalized tubes a charge sometimes builds up on the screen, since the electrons must take a higher resistance path (the glass envelope) to the aquadag. Screen charging will build up a voltage which will deflect and distort the pattern being displayed.

Another benefit of metalizing is the reduction of light emanating from the radiant cathode. Cathode glow can be transmitted through the cathode-ray tube to the phosphor screen. CRT metalizing minimizes the transmission of cathode glow which is of importance when photographing displays which require the camera shutter to be open for long periods of time.

TABLE III lists the various Fairchild Oscilloscopes with their tube types, accelerating potentials, metalizing and standard phosphors. The listing includes optional phosphor types which are stocked by Fairchild. Other phosphors are available upon special request.

Table III

CATHODE-RAY TUBE CHARACTERISTICS

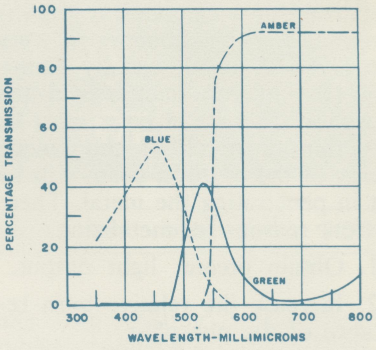
Instrument Type	Standard Tube Type	Accelerating Potential KV	Metalized	Standard Phosphor	Stocked Optional Phosphors
304-A	5ADP	3	No	P31	P1,P2,P7,P11
401-B	K1931	5	Optional	P31	P1,P2,P7,P11
403-B	K1931	5	Optional	P31	P1,P2,P7,P11
411	5ARP	2.5	No	P31	P1,P2,P7,P11
425	K1736	12	Yes	P31	P1,P2,P7,P11
436 Monitor	AW17-69	10	Yes	P 4	
Indicator	K2165	10	Yes	P31	P2,P7
440	K1931	5	Optional	P31	P1,P2,P7,P11
700	KC2308	2.7	No	P31	P1,P2,P7,P11
701	KC2308	2.7	No	P31	P1,P2,P7,P11
702	KC2308	2.7	No	P31	P1,P2,P7,P11
704	KC2308	2.7	No	P31	P1,P2,P7,P11
765/766/767	K2130	5.1	Yes	P31	P2,P7,P11
765-H/766-H/767-H	KC2321	13	Yes	P31	P2,P7,P11
777	KC2388	13	Yes	P31	P2,P7,P11
757	KC2382	14	Yes	P11	P31

Table IV

LIGHT TRANSMISSION THROUGH STANDARD COLOR FILTERS

Phosphor	Filter	Percent Light Transmittal
P1	Green	53%
	Blue	15%
	Amber	5%
	Polaroid	60%
P2	Green	52%
	Blue	8%
	Amber	12%
	Polaroid	60%
P4	Green	0%
	Blue	52%
	Amber	0%
	Polaroid	60%
P7 BLUE Component	Green	0%
	Blue	53%
	Amber	0%
	Polaroid	60%
YELLOW Component	Green	40%
	Blue	5%
	Amber	60%
	Polaroid	60%
P11	Green	0%
	Blue	54%
	Amber	0%
	Polaroid	60%
P31	Green	52%
	Blue	15%
	Amber	0%
	Polaroid	60%

Figure 4



SPECTRAL TRANSMISSION CHARACTERISTICS OF COLOR FILTERS

COLOR FILTERS

The use of a color filter in front of a cathode-ray tube reduces the light output but increases the contrast between the trace and the unexcited portion of the screen. By using a filter which has the same color as the trace the contrast can be improved. The light from the phosphor passes through the filter and is attenuated. However, the ambient light which is usually reflected from the faceplate is absorbed as it passes through the filter to the screen and again as it is reflected from the faceplate of the cathode-ray tube. This causes the trace to stand out more clearly.

A color filter also can be used to select a limited bandwidth of light from the total spectrum. The P7 phosphor which has a blue-green emission during excitation and a yellow afterglow, can be used as both a long and medium-short persistence phosphor by using color filters. The yellow component of the P7 phosphor has the long persistence characteristic. If a blue filter is used this component will be almost totally absorbed, thereby reducing the long persistence characteristic of the phosphor. Since the blue component which can pass through the blue filter has a medium-short persistence, the apparent persistence characteristics of the P7 phosphor have been effectively altered by the use of a color filter. Conversely an amber filter would be used if a long persistence characteristic is desired. Spectral transmittance of light through standard Fairchild Filters, and percentage of attenuation of spectral peaks of various phosphors are shown in TABLE IV. Clear plastic used for the scale will absorb about 10% of the emitted light energy and will therefore have only 90% transmission. Internal graticule CRT's are generally equipped with a non-reflective glass face plate which increases contrast but also causes a light attenuation of approximately 10%.

This discussion of Cathode-Ray Tube Phosphor Characteristics has been prepared to assist the user of oscilloscopes. Information can be used as a guide in choosing the proper screen for a particular requirement or for modifying existing equipment for new applications. Additional information can be found in "Photo Recording from Cathode-Ray Tubes" published by Fairchild* and from your local Fairchild Field Engineer who is always ready to assist in selecting the proper instrumentation for your application. If your requirements are very unusual, your local field engineer will arrange for you to consult with the applications engineering staff at the factory in Clifton.

*"Techniques of Photo Recording from Cathode-Ray Tubes" — Library edition P/N 67041861 .... $4.50

REFERENCES

1 Optical Characteristics of Cathode-Ray Tube Screens
Formulated by — JEDEC Electron Tube Council
JEDEC Publication #16

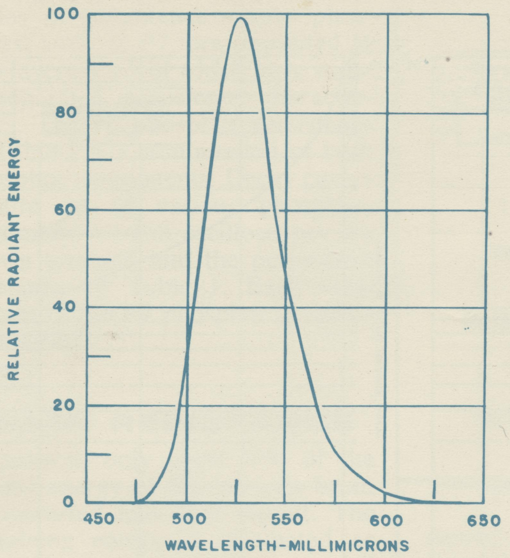
2 The Cathode-Ray Tube and Typical Applications

3 Techniques of Photo Recording from Cathode-Ray Tubes
Scientific Instrument Department
DuMont Laboratories, Divisions of Fairchild Camera & Instrument Corporation

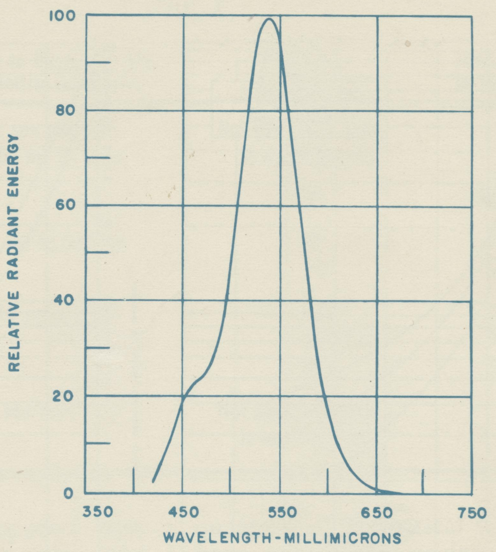
4 Typical Absolute Spectral Response Characteristics of Aluminized Phosphor Screens
ITT Components & Instrumentation Laboratory

by Edward Marrie — Staff Applications Engineer

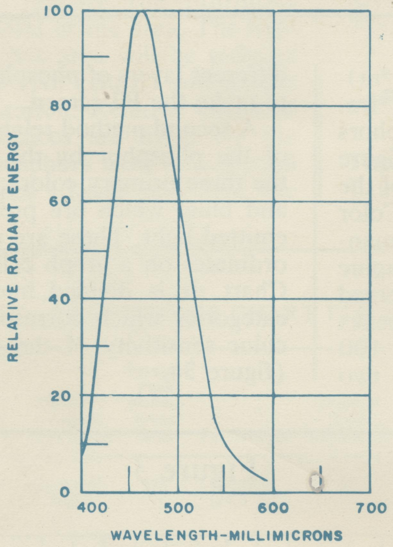
SPECTRAL ENERGY CURVES OF OSCILLOSCOPE PHOSPHORS



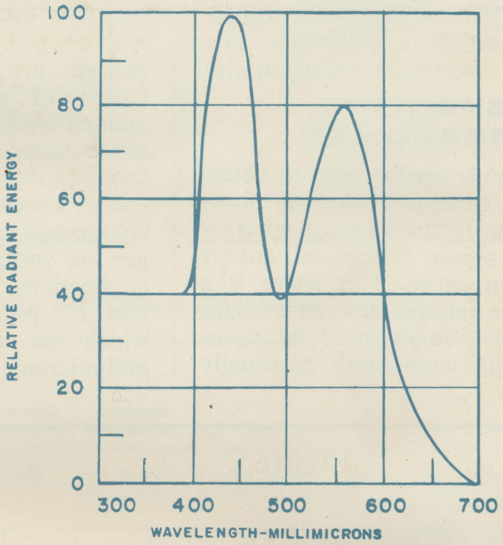
SPECTRAL ENERGY DISTRIBUTION CURVE
OF P1 PHOSPHOR



SPECTRAL ENERGY DISTRIBUTION CURVE
OF P2 & P3 PHOSPHORS



SPECTRAL ENERGY DISTRIBUTION CURVE
OF P11 PHOSPHOR



SPECTRAL ENERGY DISTRIBUTION CURVE
OF P7 PHOSPHOR

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